Extended Virtual Presence of Therapists through Home Service Robots

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1. INTRODUCTION
The use of robots in rehabilitation is an increasingly viable option, given the shortage of well-trained therapists who can address individual patients’ needs and priorities. Despite the acknowledged importance of customized therapy for individual patients, the means to realize it has received less research attention. Many approaches rely on rehabilitation robots, such as InMotion [3], where therapy customization is achieved by physically assisting patients when they cannot complete expected exercise movements. Consequently, it is important to accurately detect the patients’ unsuccessful efforts to make exercise movements using various signals. An example that utilizes electromyography signal can be found in Dipietro et al. [1]. These approaches lack of adaptive therapy programs where generic exercise targets do not necessarily address the specific needs/deficit of individual patients nor impose appropriate challenges.

Recently, some attempt to adapt the difficulty levels of exercise programs based on patient performance. For instance, Perry et al. increase the difficulty levels of exercise games when patients exceed predefined achievement thresholds [8]. Shirzad et al. explore various supervised learning methods to predict patients’ intention to adjust the difficulty levels of games [9]. However, these approaches rely on generic games with predetermined exercise programs and difficulty levels. Also, they do not allow therapists to prescribe exercise targets or specify difficulty levels directly. Jung et al. allow therapists to select exercise targets to meet the specific needs of individual patients [7]. However, their approach encodes the targets in the Cartesian space and requires the frequent intervention of therapists to re-select the targets as the motor performance of patients change.

We advocate several new features in the interaction between clients and therapists in the course of therapy, which we call the extended virtual presence of therapists in residential settings. First, we propose to accumulate the motor performance data of an individual patient along with the corresponding exercise targets during therapeutic exercises delivered by a therapist. This record of the therapy and its outcome can be mined to reveal the characteristics of exercise targets for generating autonomous therapies. Second, we advocate the use of intelligent user interface and machine learning algorithms to capture the therapist’s decision making process in the patient’s motor performance feature space. The learned results may be used to provide adaptive therapy during automated sessions according to the therapist’s strategy.

2. PRELIMINARY RESULTS
2.1 Therapy through Service Robots
The efficacy of adaptive therapy programs using a service robot was investigated through a single-subject case study. The participant in this study was a 73-year-old male who experienced a stroke 10.5 years prior to enrollment and presented with moderate hemiparesis. He scored 32 (out of 66) on the Fugl-Meyer Assessment (FMA) at the baseline test. Before the onset of the study, the therapist assessed the motor performance of the patient and determined exercise targets that can be attained by the patient with some efforts. The positions of these targets were subsequently adjusted to increase difficulty if the patient exceeded the required performance threshold. Throughout the therapeutic exercises, he was instructed to make voluntary arm movements without external physical assistance. He had total of fifteen sessions for five weeks. Each session consists of three different types of reaching exercises. For given targets, the patient was instructed to reach and touch them by instructed arm movements (Figure 1).

After the end of the five-week study, the motor performance improvement was observed in the FMA where the patient was able to score 34. The task-specific measures in Figure 1b show that the average distance of the exercise targets from the last session was significantly greater than that from the first session ($p < 0.01$, $df = 80$). Between the target adjustments (marked by red vertical lines), the duration taken for the patient to attain the same targets reduced over time (Figure 1c), which corroborated the observed improvement in the FMA score. This confirms the earlier reports by Jung et al. [4, 5] and suggests that, without any external physical assistance, patients may be able to achieve observable improvements by presenting target exercises of appropriate difficulties. This emphasizes the importance of adaptive exercise programs.

2.2 Learning Therapy Strategies
We assume that the therapist’s decision making criteria may be reflected in the runtime performance of the patient during the prescription of therapeutic exercises. The characteristics of exercise targets are formulated as topic modeling. Specifically, in this work, we employ Latent Dirichlet Allocation (LDA). In each therapy session, we assume that the therapist determines exercise targets $p = [p_1, \ldots, p_N]^T$. For each exercise target $p_n$, in the Cartesian space, the patient’s motor performance $x_n = [x_1, \ldots, x_M]^T$ are measured where $M$ is the number of features describing the motor per-
3. DISCUSSION

Motivated by the promising results, we plan to execute additional single-subject case studies to further investigate the efficacy of adaptive therapy through service robots. More motor performance features, such as cognitive/physical delays and motor unit counts, will be explored to make the feature space richer. Since the size of data that can be acquired in practice is small, investigation in learning algorithms that can cope with small data will be also necessary. In order to address the evolving strategies of the therapist within a session, we plan to investigate a composite model, which integrates LDA with a hidden Markov model [2].

We also plan to investigate the use of personalized database in order to manipulate the patient’s environment, e.g. relocating objects at home, and to assist patients in the activities of daily living. Service robots may directly address activities and objects of daily living that contribute to independence in the residential setting.

Through the proposed approach, we envision that patients can receive quality therapy from remotely located therapists using home service robots and that therapists can be more productive.

4. ACKNOWLEDGMENT

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5. REFERENCES